Using Multi-Layer Routing to Provision Services across MPLS/GMPLS Domain Boundaries

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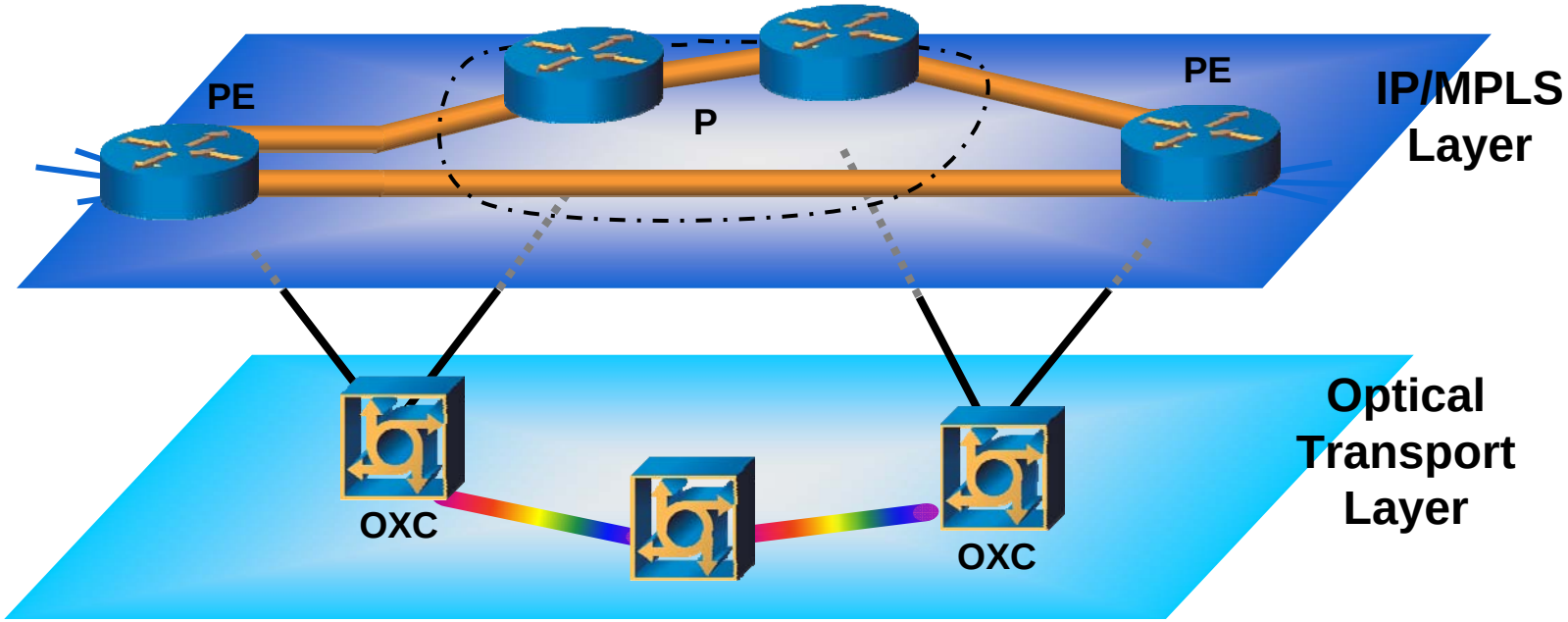
Problem Statement

- Today's Internet infrastructure is actually built as a multi-layer network
- Also true for public networks that provide private non-Internet IP services
- IP/MPLS routers use optical interconnection services to provide inter-router interconnectivity
- Optical networks can be SDH, SONET, WDM, GFP, RPR, ASON, ….
- In many cases, optical provisioning is still manual
- Even if automated, optical routing is separate from packet-payer routing

IP & Optical Layers Have Separate Routing



- IP/MPLS network uses IGPs (OSPF, IS-IS) and EGPs (BGP) for packet routing at IP layer
- Also use OSPF-TE and ISIS-TE with RSVP-TE for MPLS traffic engineering
- Optical layer has its own optical path routing separate from packet routing
- Optical layer outages may cause alarms and non-coordinated re-routing at both layers

The Benefits of Multi-Layer Routing

- Coordinating routing between the packet and optical layers can have a number of benefits
  - Optimizes packet paths and traffic engineering through both the packet and optical layers
  - Allows the establishment of optical-layer short-cut transport tunnels between topologically separated routers at packet layer
  - Reduces packet latency by removing router hops
  - Coordinates alarms and re-rerouting following optical trunk or switches outages

How Can This Be Accomplished?

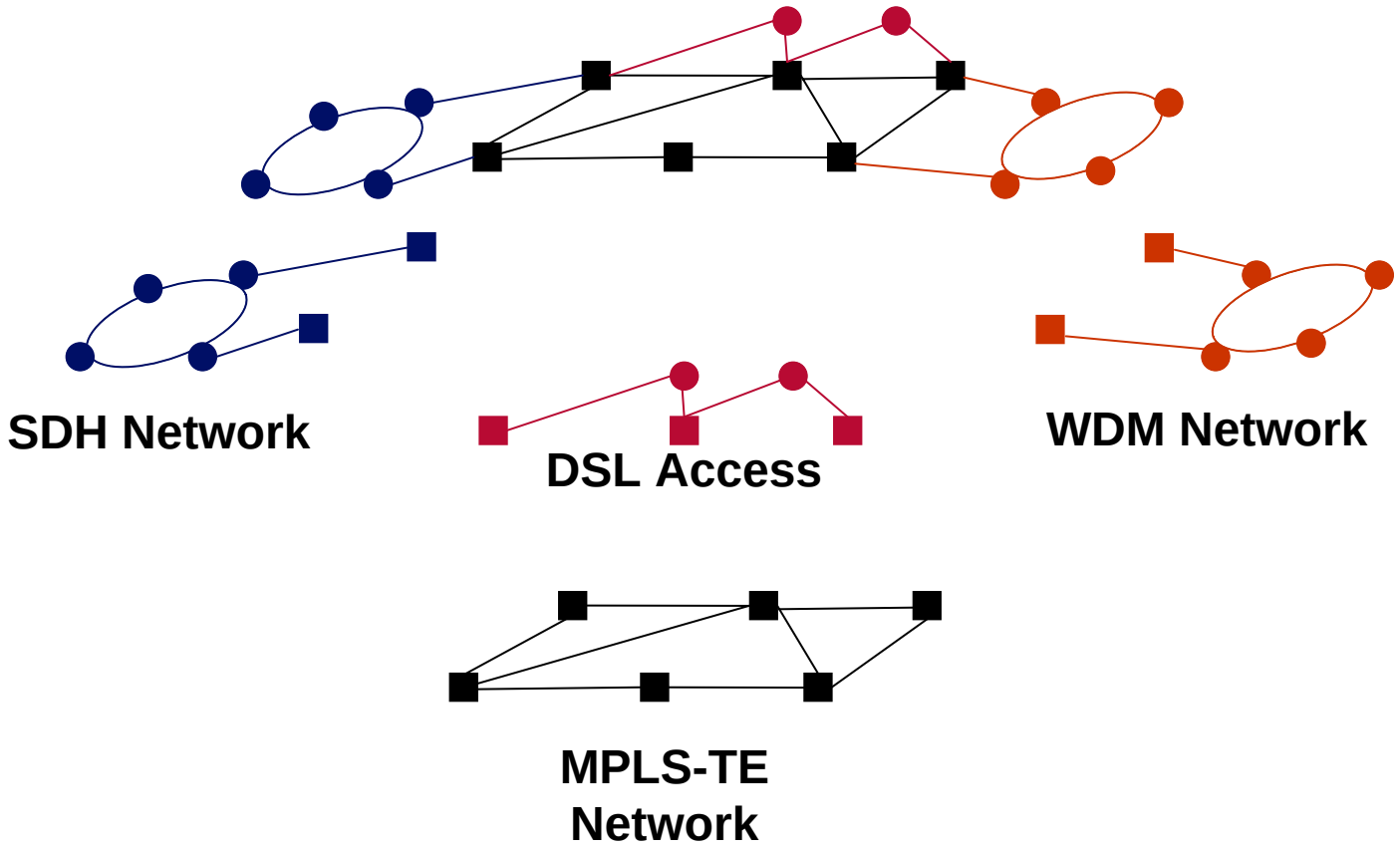
- Common flexible control method that understands layering
  - Traffic engineering path computation that understand layered networks
    - Provides service routing given view of potential/available server layer resources
  - Signaling mechanisms that coordinate calls in different layers
  - OSSes that can handle integrated views of layer networks
    - Relate services requests (client layer calls) to server resources in use
  - Definitions for server layer resources other than SONET/SDH
- An Added Benefit: Integrated operations
  - Operations convergence possible due to common control methods

Generalized MPLS (GMPLS) Meets the Requirements

- Establishes a common control plane for different networking technologies
  - Converge Packet, Cell, TDM, and Optical administrative controls
- Automates connection management for all traffic types
  - Path setup and management (for Packet, Cell, TDM, and Optics)
- Handles topology changes automatically
  - Self-discovery and dynamic configuration of network resources
- Provides static and dynamic path reroutes and restoration
- Supports Peer-to-Peer and Overlay network models
  - Integration of optical switches, optical transport, and label switching routers

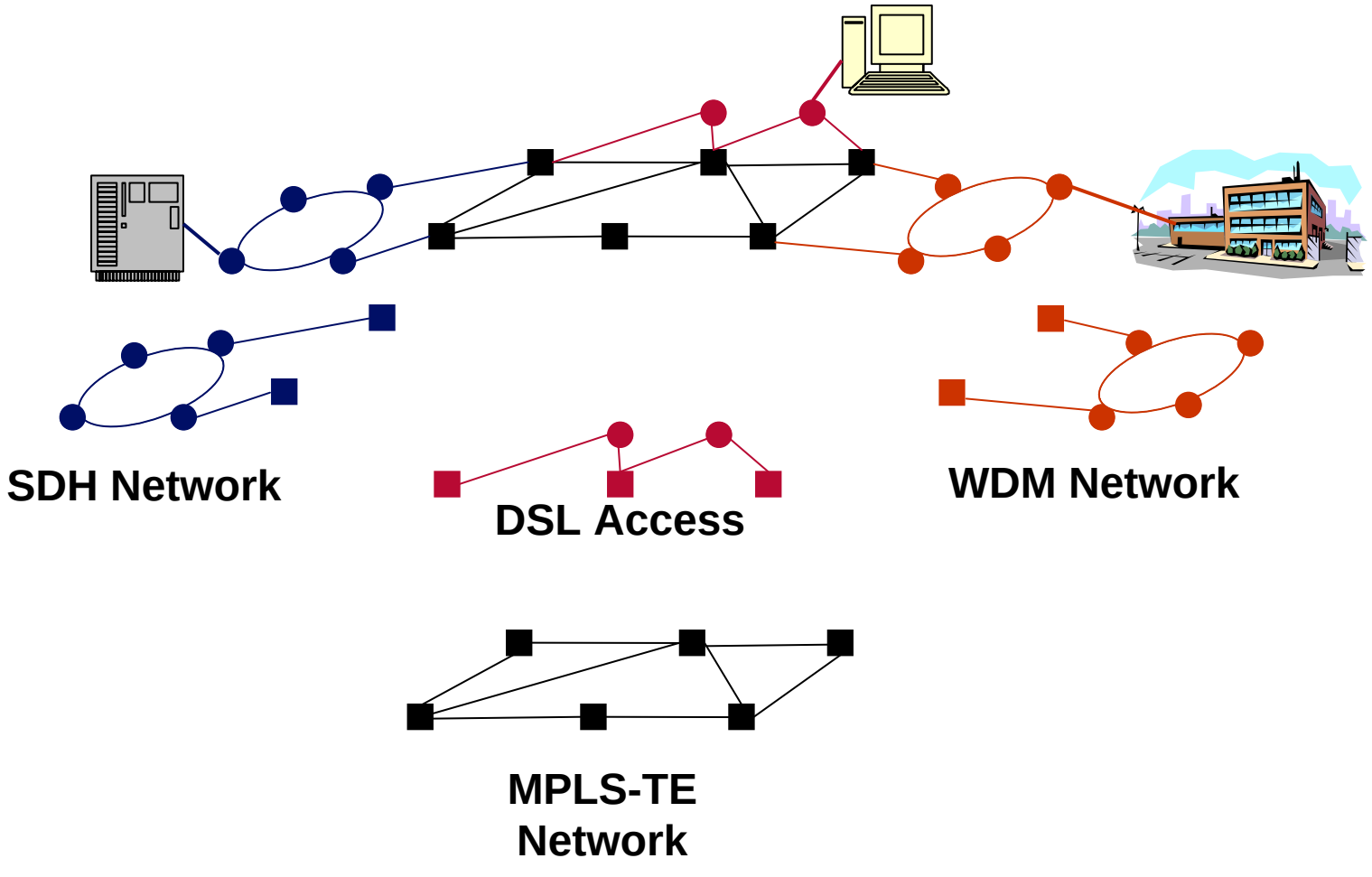
Making Path Computation Layer Aware

- **Routing today treats different technologies as separate topology graphs**



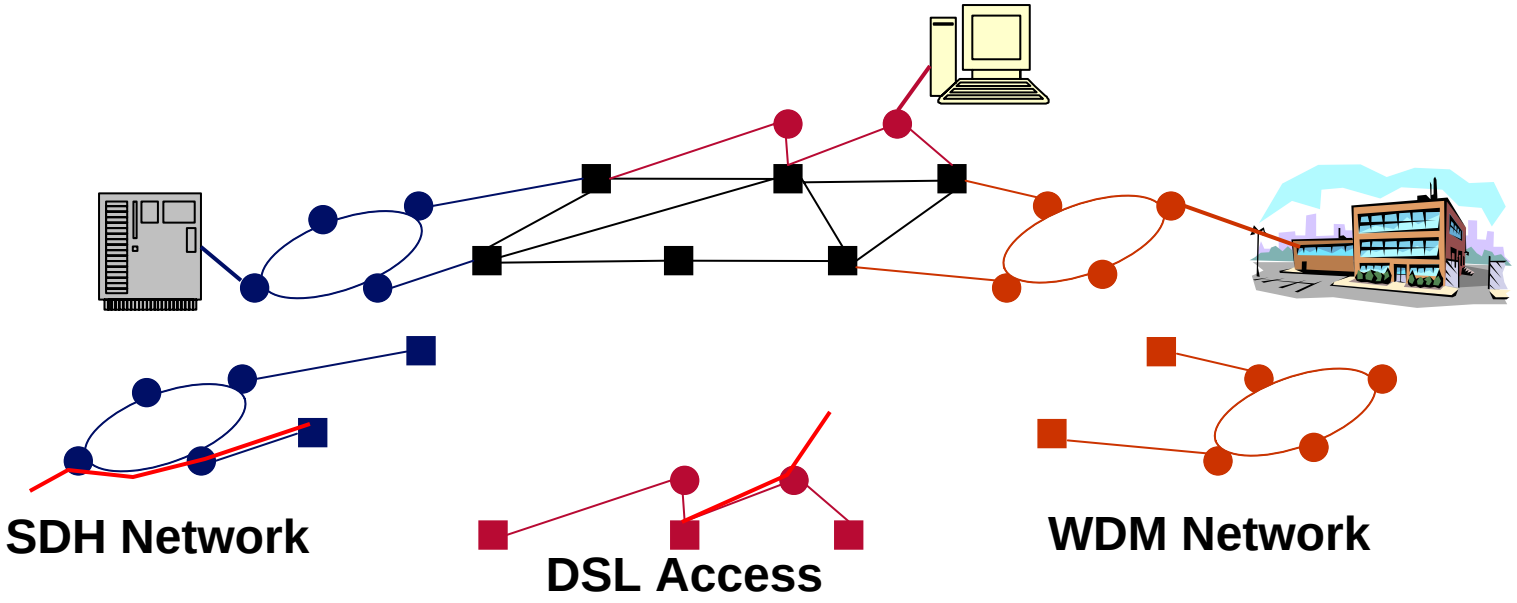
Making Path Computation Layer Aware

- **Normal Path Computation cannot find paths between endpoints on different islands**



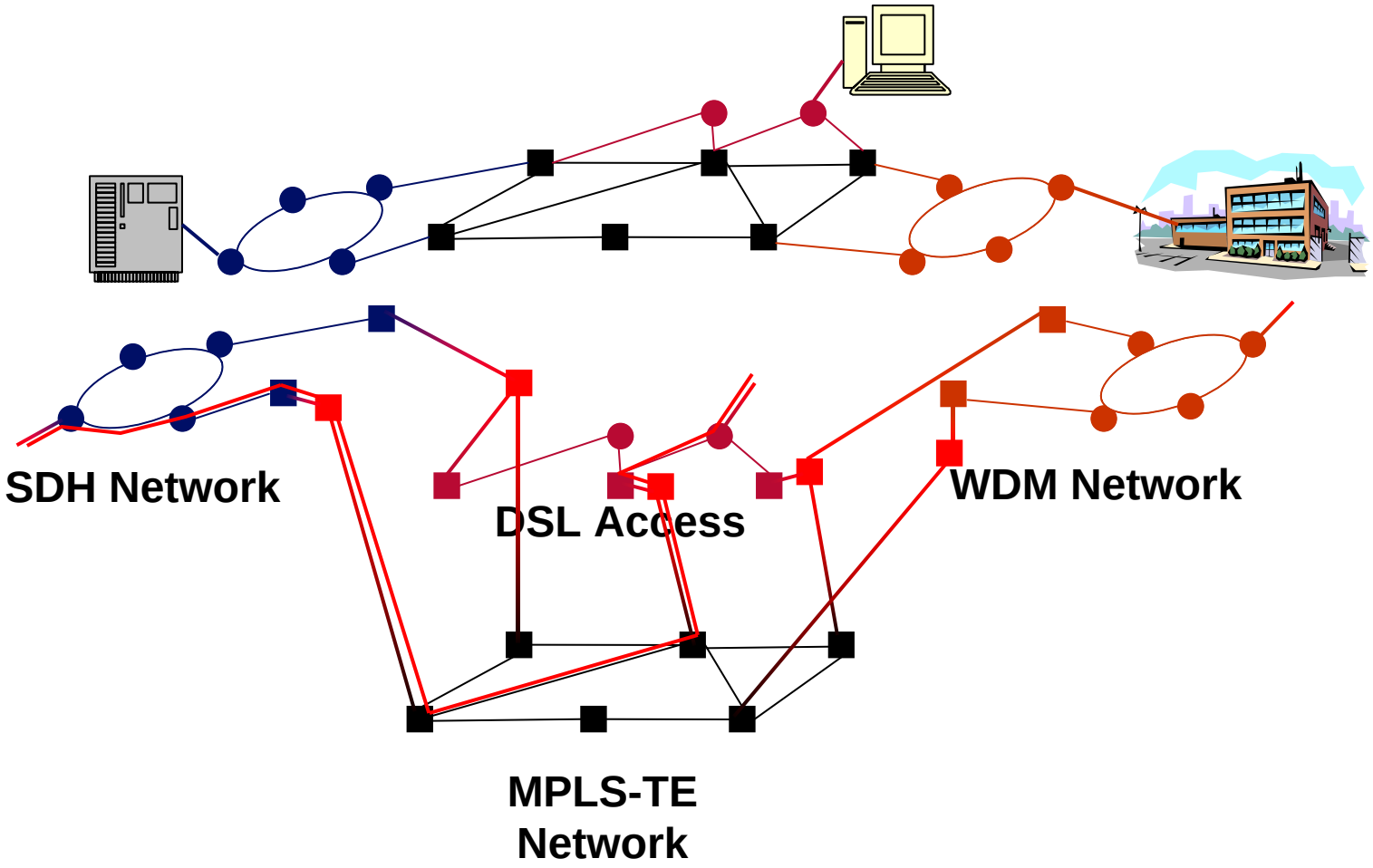
Making Path Computation Layer Aware

- As a result, end-to-end services are separately routed by each island, and interconnected by hand



Making Path Computation Layer Aware

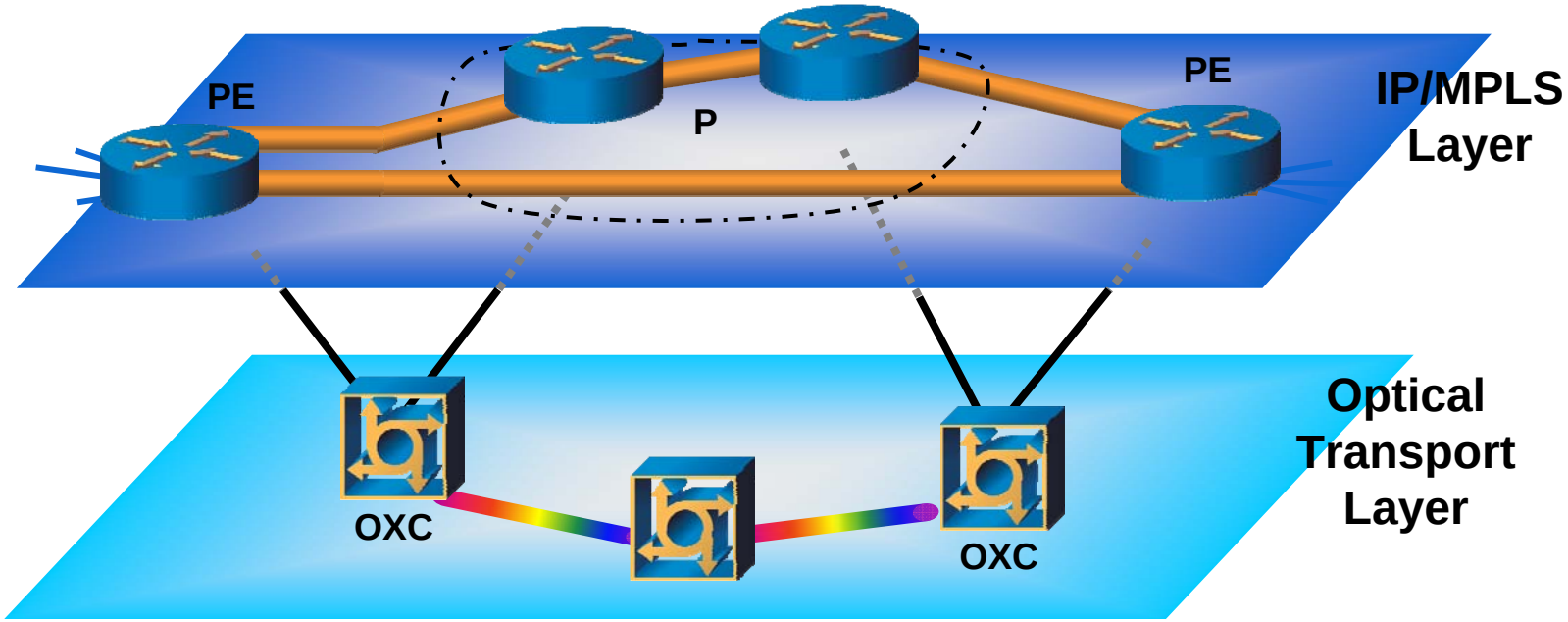
- By merging the graphs and adding client/server adaptation costs, the graph becomes continuous



Making Path Computation Layer Aware

- GMPLS routing extensions
  - Link attribute announcements that:
    - remove ambiguity of adaptations supported
    - announce adaptations in a technology independent manner
      - necessary to allow for source routing to be done anywhere
    - include link costs that take into account:
      - different costs for each layer supported by a link
      - cost to utilize adaptation
  - Path computation algorithm that:
    - understands multiple matrices per node
    - updates “signal stack” when adaptations are pushed/popped

IP & Optical Layer Combination Practical Example



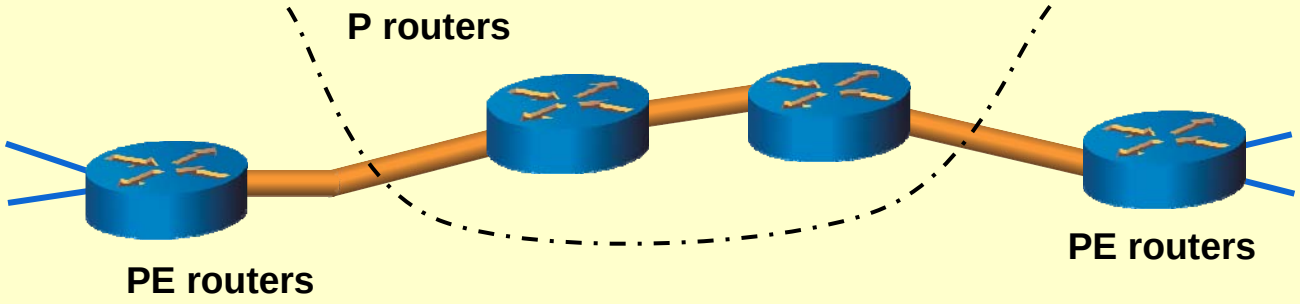
Major Objectives:

-Minimize electrical packet processing in core

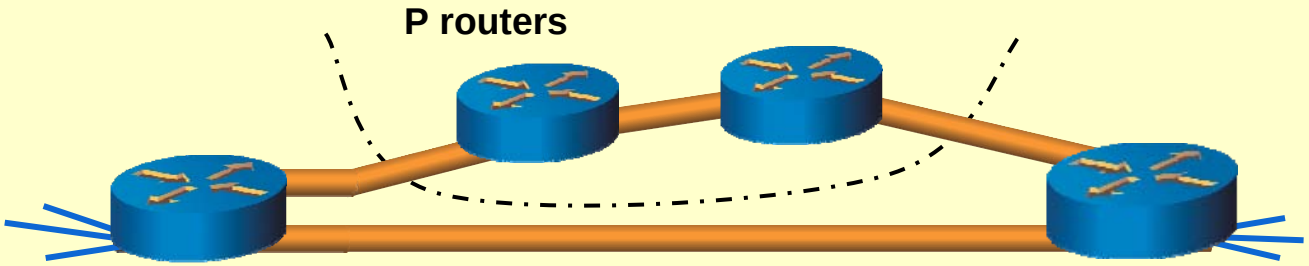
-Minimal changes to existing IP/MPLS routers

-Take advantage of TE in both networks – carry out multi-level TE

Optimal Design of an MPLS Core Network



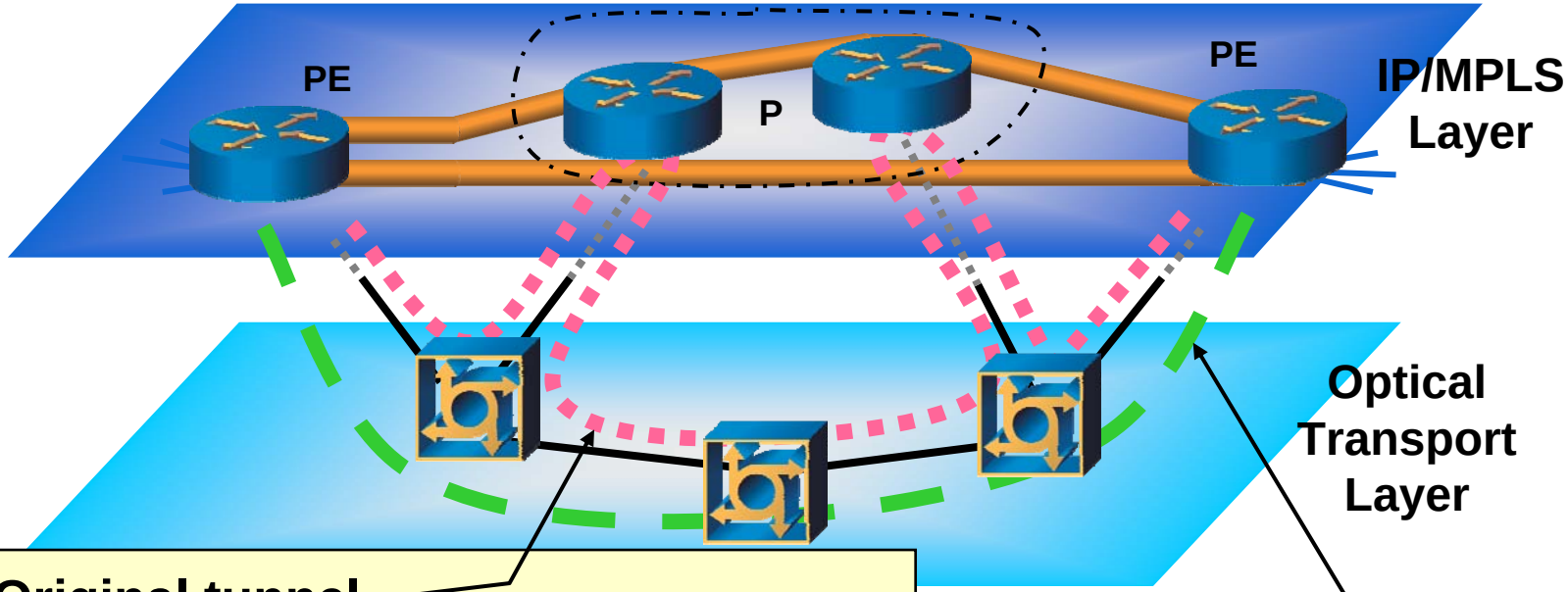
- LSP mesh between PEs originally traverses P routers



- Direct PE-PE optical tunnels preferable where *sufficient* direct traffic exists
- Move LSPs to direct route reducing P-router load

Feasible and cost-effective with GMPLS

Essence of Multi-Layer Core Optimization



- **Original tunnel**
  - Six router interfaces
  - Forwarding on two P routers
  - Ten transport interfaces
  - 2x bandwidth on links to P routers

- **Direct tunnel**
  - Two router interfaces
  - Six transport interfaces

GMPLS affords *dynamic, optimal size* direct tunnels – without necessity to wait for transport service orders

Standards Activities

- IETF – GMPLS Multi-layer and multi-region networks
  - Defines consolidated traffic engineering and topology databases and resource control
  - draft-shiomoto-ccamp-gmpls-mrn-reqs-03.txt
  - draft-leroux-ccamp-gmpls-mrn-eval-02.txt
- ITU-T – ASON Multi-layer calls and multi-layer routing
  - G.8080 Amendment 2
- OIF – UNI 2.0 Ethernet Services & E-NNI Routing
  - Multi-layer routing and call signaling
  - Global demonstration in conjunction with Supercomm 2005 (13 vendors and 7 service providers: AT&T, China Telecom, Deutsche Telecom, France Telecom, NTT, Telecom Italia, Verizon)
  - White paper at http://www.oiforum.com/public/downloads/2005InterOpDemoWhitePaper_FINAL.pdf

Conclusion

- MPLS is the industry-standard mechanism for IP network traffic engineering
- GMPLS is being deployed as optical network equipment replacement picks up
- Integration of MPLS and GMPLS for traffic engineering allows coordinated, optimal use of optical and packet network resources
- Routing and signaling procedures to support layering are in development
  - Standardization activities underway in IETF, ITU, and OIF
  - Multi-vendor interoperability already demonstrated

Thank you!

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